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REDUCING ENERGY INPUT COSTS AND ASSOCIATED GREENHOUSE GAS EMISSIONS IN COTTON

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Abstract

Within highly mechanised agricultural productions systems such as the Australian cotton industry, operational energy inputs represent a significant cost to growers. Through an assessment of seven case study sites, it was shown that the total energy inputs were significantly influenced by the management and operation methods adopted, and ranged from 3.7-15.2 GJ/ha of primary energy, at a cost of \$80-310/ha and 275-1404 kg CO_2 equivalent/ha greenhouse gas emissions. Among all the farming practices, irrigation water energy use was found to be the highest and was typically 40-60% of total energy costs (wherever water is pumped). Energy use of the harvesting operation was also significant, accounting for 20% of overall direct energy use. If a farmer moves from conventional tillage to minimum tillage, there is a potential saving of around 10% of the fuel used on the farm. Compared with cotton, energy used in the production of other irrigated crops on these farms was generally half of cotton. This was due to less intensive management required for these crops, leading to the lower number of farming operations (passes) carried out (generally about 10, in comparison with 17-18 for cotton) and reduced irrigation requirements.

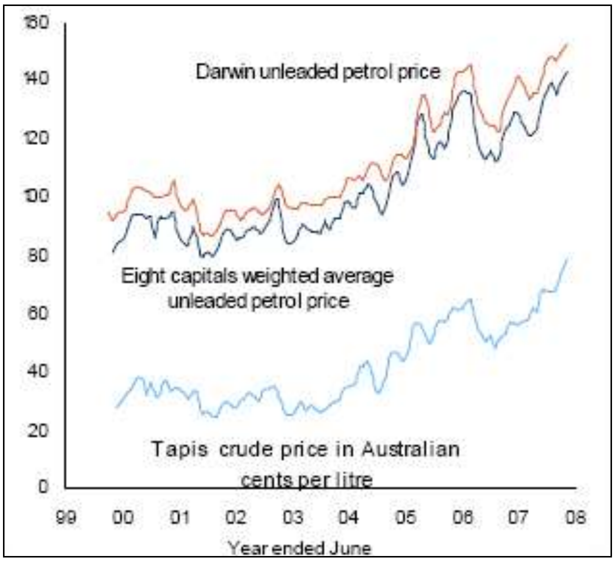

Figure 1 Unleaded petrol prices in Australia and Tapis crude oil prices (cents per litre)

Introduction

On-farm energy efficiency is becoming increasingly important in the context of rising energy costs (Fig.1) and concern over greenhouse gas (GHG) emissions. Energy inputs represent a major cost and one of the fastest growing cost inputs to primary producers. The Australian cotton growing industry is highly mechanised and heavily reliant on fossil fuels (electricity and diesel). Within highly mechanised farming systems such as those used within the cotton industry, energy inputs can represent 40 – 50% of the cotton farm input costs. Given the major dependence on direct energy inputs and rising energy costs, energy use efficiency is an emerging issue for the Australian Cotton Industry. Rational and efficient use of energy is essential for sustainable development in agriculture.

Operational Energy Use in Agriculture

Extensive research has been conducted on energy use and conservation both in agriculture (Pellizzi et al, 1988; Stout, 1989; Tullburg and Wylie, 1994) and in other industries (Eastop and Croft, 1990). Table 1 summarizes the published energy use data reported for different crops in different countries. At the current market condition, 1 GJ of energy would typically cost Australian farmers \$20-25. It can therefore be seen from Table 1 that energy inputs represent a major cost to the producer within most production systems.

Table 1: Key published energy performance data

Crops	Direct Energy Input (GJ/ha)	Indirect Energy Input (GJ/ha)	Total Energy Input (GJ/ha)	Researchers	Country
Wheat	2.5 ~ 4.3			Pellizzi et al (1988)	Europe
Wheat			16 ~ 32	Tsatsarelis (1993)	Greece
Maize	4.7~5.0			Pellizzi et al (1988)	Europe
Conventional arable	5.8	15.0	20.8	Cormack (2000)	UK
Organic arable	3.8	2.3	6.1	Cormack (2000)	UK
Rice			64.89	Pretty (1995)	USA
Cotton	21.14	28.59	49.73	Yilmaz et al (2005)	Turkey
Cotton			82.6	Tsatsarelis (1991)	Greece

In addition to the information presented in Table 1, Singh (2002) also showed that cotton has the highest energy usage among wheat, mustard, maize and cluster bean. Yaldiz et al. (1993) reported that fertilizers and irrigation energy dominated the total energy consumption in Turkish cotton production. Yilmaz et al (2005) showed that the energy intensity in agricultural production was closely related with production techniques. He estimated that cotton production in Turkey consumed a total of 49.73 GJ/ha energy, consisting of 21.14 GJ/ha (42.5%) direct energy input and 28.59 GJ/ha (57.5%) indirect energy input. Total sequestered energy in Greece was found to be 82.6 GJ/ha with irrigation and fertilizers as major inputs. Cotton yield was 1024 kg/ha lint and 2176 kg/ha seed.

Energy Efficiency Audit and Framework

Energy audits are a crucial part of the energy and environmental management process. Energy audits refer to the systematic examination of an entity, such as a firm, organisation, facility or site, to determine whether, and to what extent, it has used energy efficiently. They determine how efficiently energy is being used, identify energy and cost saving opportunities and highlight potential improvements in productivity and quality. They may also assess any potential energy savings, for example, through fuel switching, tariff negotiation and demand-side management.

There is currently a lack of systematic research for energy use in agriculture. As a result, there is currently a lack of "rules of thumb" for the calculations/estimation of the return of energy improvement and investment for agriculture. There is also an urgent need to develop a detailed model report/protocol/template so that effective and widespread energy audits can take place in agriculture. This is necessary to reduce the costs of energy audits and from the quality assurance point of view if in the future an industry energy auditing advisory service or consultancy is to be introduced on any large scale. In response, a methodology and tool (ie EnergyCalc) was developed for undertaking agricultural energy assessments. EnergyCalc also converts energy inputs into greenhouse gas emissions. The methodology and terms used to describe different levels of energy audits are discussed below.

Energy Audit Level 1

A level 1 audit is the simplest and cheapest form of energy audit and is referred to as a preliminary audit or overview of the whole farm. This involves collating all the energy use data from the farm, including the total fuel (diesel, petrol and other fuels) and the total electricity energy consumed. It is generally expected that these figures will be available from the farm receipts. The total energy uses are then divided by the total farm production (eg, head of cows, bales of cotton, tonnes of wheat) to derive the energy insensitivities of the site. Usually no additional tools are required for this level of audit.

Energy Audit Level 2

A level 2 audit is referred to as a standard / general audit and is effectively a desktop study of the energy breakdown or itemised account of energy usage across the farm. A Level 2 audit aims to reach an accuracy of ±20%. A Level 2 audit will generally involve a site visit to discuss energy use and different operations. Energy usage / concerns are noted as well as any other site specific information that could be useful such as electric motor sizes, pumping equipment, tractors and vehicles. Either during the energy audit or through subsequent correspondence with the site representative relevant information is collected to evaluate the total energy usage and production on the site.

Energy Audit Level 3

A Level 3 energy audit is a comprehensive study of the energy usage of farming operations. A level 3 assessment utilises site specific data either gained from on-site testing or through data/records provided by a site representative. Examples of sensors used may include pressure (irrigation head pressure), flow rate, engine RPM, tractor travel speed, torque, load and temperature etc. A data logger may also be required to record the data for a considerable period of time to determine performance and to identify optimised machine settings. It is expected that a level 3 energy audit will be able to reach an accuracy of ±10%.

It is noted that the system suggested above for agriculture is similar to that used within the building industry (Australian/New Zealand AS/NZS 3598:2000). However, some differences do occur at the detail in which some measurements are conducted, particularly for a level 3 audit. This is mainly because:

- Agriculture is significantly influenced by seasonal factors and the energy use profile for agriculture may vary on both an annual and daily basis.
- Much more diverse types of machinery are used in agriculture and different machines may be used at different times.
- Fuel use, rather than electricity, is most important for agriculture.
- On-site operational energy is not necessarily the dominate energy user for agriculture.

Energy Audit Level 2 Plus

In many situations, due to the project cost and time consideration, a farmer may not wish to conduct a full level 3 audit of his/her property. Instead, he/she may just want a level 2 audit, but with the addition of a detailed investigation into the energy efficiency of a specific operation where the greatest energy consumption has been identified from level 2. In this case, we may just call this kind of audit as Energy Audit Level 2 Plus.

Greenhouse gas emissions from the fuel use of agricultural production

With the increased community concern on global warming and climate change, the greenhouse gas emissions from the fuel use of agricultural production will also need to be evaluated. Conversion of fuel use to greenhouse gas emissions can be determined by algorithms outlined in the Australian Greenhouse Office (AGO) Factors and Methods workbook (2008). It is important to note that these calculations only relate to greenhouse gas emissions from direct energy use, and has not included the (biological) effect due to soil tillage/disturbance and applications of nitrogen fertilizer. The latter will change significantly with both time and locations.

On-farm Energy Assessments

To assess current practices in terms of energy efficiency, seven case studies were examined to determine the direct energy use for various farming enterprises in the cotton industry. The data for cotton farms A and B were extracted from Chudleigh, et al (2007), while data for the other case studies (Farms C to G) was obtained from farmer interviews (similar to a level 2 audit). The farms included in the study covered a range of farming regions and farming practices (eg, conventional tillage, minimum tillage, dryland farming, and irrigation) in both NSW and Queensland.

Key elements of each case study include the following and are presented in Table 2. For some of the case studies, basic farm data (eg, irrigation head pressure) was used to reflect the operating costs recorded by the grower and may not reflect physical setup of the pump operation.

To demonstrate and compare the relative energy uses for different crop rotation practices, three case studies (Farms E, F, G) of mixed farms (producing cotton and other crops) were also included. Dryland farming was also practiced in farms B, E and G (for other crops only, not for cotton).

Table 2 Key farming methods (cotton production only)

	Tillage method	Irrigation method	Water Sources
Farm A	Conventional tillage	Diesel pump	Surface water
Farm B	Conventional tillage	Diesel pump	Surface water
Farm C	Minimum tillage	Gravity feed	Surface water
Farm D	Conventional tillage	Diesel pump	Ground water
Farm E	Minimum tillage	Diesel pump	Ground water
Farm F	Conventional tillage	Electric pump	Surface water
Farm G	Minimum tillage	Electric pump	Ground water

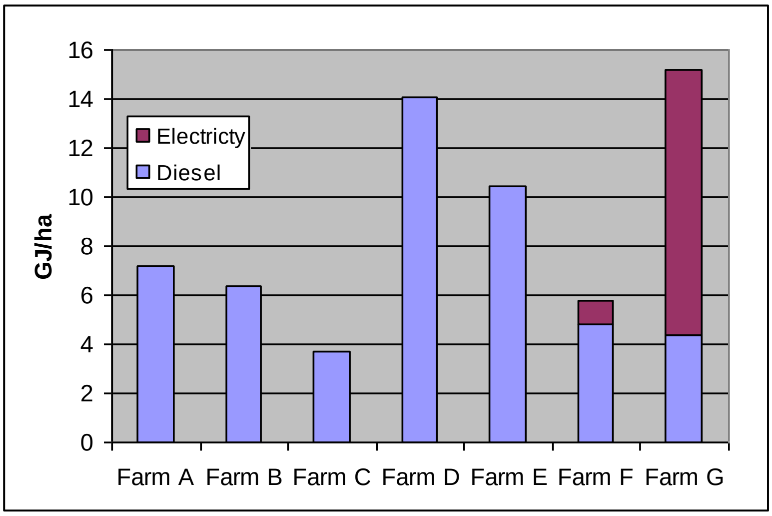

Figure 2 (Primary) energy inputs of case study farms (cotton production only)

Based on the calculated results for each case study (Fig.2), the total energy inputs ranged from 3.7-15.2 GJ/ha of primary energy, corresponding to 275-1404 kg CO2 equivalent/ha greenhouse gas emissions. Diesel energy inputs ranged from 95 to 365 litres/ha, with most farms using 120 to 180 liters/ha.

The results also showed that values for energy inputs vary widely (300%). Farm C used the smallest amount of diesel energy (95 litres/ha, or 3.7 GJ/ha) due to gravity fed surface irrigation and minimum tillage. Farm D used the largest amount of diesel energy (365 liters/ha) due to irrigation water which was double pumped. That is, the water was first pumped out of a bore and into an on farm storage and then pumped out of the on farm storage and onto the field. This significantly increased the irrigation energy use (70% of the total energy cost) for this farm. A similar situation also occurred for farm E (62%) and G (51%). The total energy costs for different farms for cotton production are shown in Figure 3, assuming cost of fuel (diesel) being $0.85/L and cost electricity being $0.10/kWh.

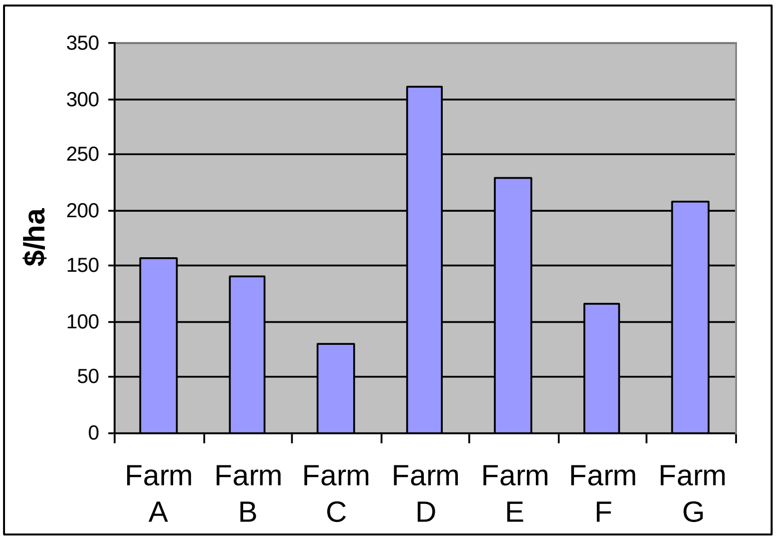

Figure 3 Total direct energy costs of case study farms (cotton production only)

Compared with cotton, the energy calculations of the case studies also indicate that the total energy use by other crops were generally much lower (wheat $42-130/ha, sorghum $60-130/ha, chickpeas $50-130/ha). Lower energy use was due to less farming operations (generally 10 passes, compared to 17-18 for cotton) combined with reduced irrigation requirements. The energy use by the cotton harvester (45 L/ha) was another factor, as it used much more energy than the other types of crop harvesters which used 10-20 L/ha of diesel. As a result, obtaining accurate measurements for harvesting energy use becomes particularly important in the context of the cotton production system.

The calculated results also showed that the energy use by tillage and other on-farm operations varied due to the number of tillage operations between different farmers (particularly if minimum tillage is practiced or not). It was shown that if a farmer moved from conventional tillage to minimum tillage (eg Farms C and E), there was a potential saving of around 10% of the fuel used on the farm. This can also be seen in the proportion of energy spent on fallow management which reduced significantly from typically 12-15% to 4-5% of the total cost (Table 3). In comparison, Farm F spent the highest proportion of energy inputs (32%) on fallow operations due to the use of both a rotary hoe and ripper (Table 3).

It can also be seen from Table 3 that values of the energy use by irrigation varied significantly between individual farms, typically between 40-60% of total energy costs for most farms. Farm G produced the highest greenhouse gas emissions (1404 kg CO2 equivalent /ha) because it used electricity to pump ground water from a bore. These results showed that effective water management was critically important, particularly when pumping costs were quite high (i.e. extracting water from bores).

Table 3 Percentage of total energy costs for different cotton farming processes

	Fallow	Harvest	In Crop	Irrigation	Planting	Post Harvest
Farm A	15%	24%	8%	40%	4%	9%
Farm B	14%	27%	3%	39%	7%	10%
Farm C	4%	54%	21%	0%	5%	16%
Farm D	7%	14%	4%	70%	1%	3%
Farm E	5%	19%	4%	62%	2%	7%
Farm F	32%	38%	7%	9%	7%	7%
Farm G	12%	21%	4%	51%	4%	8%
All farm average	8%	20%	5%	57%	3%	7%

Conclusion

Through the development of an on-farm energy audit tool, the operational energy costs for different cotton production system have been determined and compared. Depending on the management and operation methods adopted, the total energy inputs for these farms ranged from 3.7-15.2 GJ/ha of primary energy, corresponding to $80-310/ha and 275-1404 kg CO2 equivalent/ha greenhouse gas emissions.

The work has shown that water management on irrigated cotton properties is critically important; particularly those with pressurised irrigation systems or where “double pumping” from bores to storages and then to fields is practised. For surface furrow irrigation, the energy use by irrigation may vary between 40-60% of total energy costs for most farms. It has also been found that energy use of harvesting is significant, because it usually contributes around 20% of overall direct energy use. It has been shown that if a farmer moves from conventional tillage to minimum tillage, there is a potential saving of around 10% of the fuel used on the farm, plus other production advantages. Compared with cotton, the energy use by other crops are generally much smaller (approximately half).

In terms of future work, it has been identified that one of the major limitations of current research is the heavy reliance on published data from various sources. Significant work and further case studies are therefore required to establish benchmarking energy use data and to compare and evaluate energy use for alternative productions systems and impacts on greenhouse gas emissions. There is also a strong need to develop a detailed model report/manual so that effective and widespread energy audits in agriculture can take place.

This research has been limited to on-farm energy use, excluding ginning, drying and other off-farm activities. The current on-farm energy efficiency research will therefore need to be extended to incorporate further downstream processing including packaging, storage, and distribution. Such work is needed in order to better understand the main sources of overall energy expenditures and greenhouse gas footprints.

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